Current Claim Status

1. (Presently Amended, Once) An NMR measurement apparatus, comprising:
a permanent magnet;
a primary coil extending across a first surface area, the primary coil having a first depth of investigation and ~~a first an associated depth of investigation and an associated~~ vertical resolution and producing a primary RF field in a volume of earth formation;
a secondary coil extending across a second surface area, the second surface area less than the first surface area, the secondary coil having ~~a second an associated~~ depth of investigation and ~~a second an associated~~ vertical resolution and producing a secondary RF field in a volume of earth formation, the second vertical resolution higher than the first vertical resolution;
a circuit coupled to the primary coil and the secondary coil adapted to perform high resolution NMR measurements of an earth formation based on a signal received by the second coil.

2. (Original) The NMR measurement apparatus of claim 1, wherein the NMR measurements comprise a secondary coil dataset associated with NMR measurements made for a depth of investigation associated with the secondary coil .

3. (Original) The NMR measurement apparatus of claims 2, wherein a high resolution log is generated based on the secondary coil dataset.

4. (Original) The NMR measurement apparatus of claim 2, wherein the NMR measurements further comprising a primary coil dataset associated with NMR measurements made for a depth of investigation associated with the primary coil; and

5. (Original) The NMR measurement apparatus of claims 4, wherein a spin-spin relaxation estimate based on a combination of the primary coil dataset and the secondary coil dataset.

6. (Original) The NMR measurement apparatus of claim 1, wherein the depth of investigation of the secondary coil is shallower than a depth of investigation of the primary coil.

7. (Original) The NMR measurement apparatus of claim 1, wherein the depth of investigation of the secondary coil is substantially the same depth as the depth of investigation of the primary coil.

8. (Original) The NMR measurement apparatus of claim 1, wherein the NMR measurement apparatus is a centralized-type logging tool.

9. (Original) The NMR measurement apparatus of claim 1, wherein the secondary RF field is orthogonal to the primary RF field.

10. (Original) The NMR measurement apparatus of claim 1, wherein a size of the secondary coil is optimized based on a combination of the depth of investigation of the secondary coil and the primary coil and the vertical resolution of the secondary coil and the primary coil.

11. (Original) The NMR measurement apparatus of claim 1, wherein the NMR measurements are made while drilling a borehole.

12. (Original) The NMR measurement apparatus of claim 1, wherein the primary coil and the secondary coil are arranged in a non-overlapping configuration along the axis of the apparatus.

13. (Original) The NMR measurement apparatus of claim 12, wherein the secondary antenna is located near a proximate end of the main antenna measured along the longitudinal axis of the NMR measurement apparatus.

14. (Original) The NMR measurement apparatus of claim 12, wherein the secondary coil is located a distance from the primary coil that minimizes an electrical coupling between the secondary coil and the primary coil .

15. (Original) The NMR measurement apparatus of claim 12, wherein the second coil is operated in an active mode as both a transmitter and a receiver.

16. (Original) The NMR measurement apparatus of claim 15, wherein the secondary antenna selectably transmits a portion of an NMR acquisition sequence

17. (Original) The NMR measurement apparatus of claim 15, wherein the primary coil is selectably operated in either a passive or active mode.

18. (Original) The NMR measurement apparatus of claim 1, wherein at least a portion of the first surface area overlaps the second surface area.

19. (Original) The NMR measurement apparatus of claim 1, wherein the secondary antenna is embedded in the primary antenna.

20. (Original) The NMR measurement apparatus of claim 19, wherein the second coil is operated in a passive mode as a receiver of signals produced in response to a transmission by the first coil.

21. (Original) The NMR measurement apparatus of claim 19, wherein the second coil is operated in an active mode as both a transmitter and a receiver.

22. (Original) The NMR measurement apparatus of claim 21, wherein the secondary antenna selectably transmits a portion of an NMR acquisition sequence

23. (Original) The NMR measurement apparatus of claim 21, wherein the primary coil is selectably operated in either a passive or active mode.

24. (Original) The NMR measurement apparatus of claim 1, the secondary coil further comprising:

an array of secondary coils arranged in a non-overlapping configuration along the axis of the apparatus.

25. (Original) The NMR measurement apparatus of claim 24, wherein the array of the secondary coils comprises a pair of secondary coils, each of the pair of secondary

coils situated at opposite proximate ends of the primary coil measured along the longitudinal axis of the NMR apparatus.

26. (Presently amended, Once) A method for obtaining high-resolution NMR measurements of an earth formation from an NMR apparatus having a magnet, a primary coil and at least one secondary coil, the method comprising steps of:

producing a static magnetic field in the earth formation with the magnet;

transmitting at least a portion of an RF pulse sequence with the primary coil extending across a first surface area to produce an oscillating magnetic field that is substantially orthogonal to the static magnetic field;

receiving NMR signals with the secondary coil extending across a second surface area, the second surface area less than the first surface area, the secondary coil having a higher vertical resolution than a vertical resolution of the primary coil; and

calculating at least one high resolution measurement based on the received NMR signals from the secondary coil.

27. (Original) The method of claim 26, further comprising:

generating a secondary coil dataset associated with NMR measurements made for a depth of investigation associated with the secondary coil .

28. (Original) The method of claim 27, further comprising:

generating a high resolution log is based on the secondary coil dataset.

29. (Original) The method of claim 27, further comprising:

receiving NMR signals with the primary coil;

generating primary coil dataset associated with NMR signals from a depth of investigation associated with the primary coil; and

30. (Original) The method of claim 29, further comprising:

calculating a spin-spin relaxation estimate based on a combination of the primary coil dataset and the secondary coil dataset.

31. (Original) The method of claim 26, wherein the depth of investigation of the secondary coil is shallower than a depth of investigation of the primary coil.

32. (Original) The method of claim 26, wherein the depth of investigation of the secondary coil is substantially the same depth as the depth of investigation of the primary coil.

33. (Original) The method of claim 26, wherein the NMR measurement apparatus is a centralized-type logging tool.

34. (Original) The method of claim 26, wherein the secondary RF field is orthogonal to the primary RF field.

35. (Original) The method of claim 26, further comprising the step of:
optimizing the size of the secondary based on a combination of the depth of investigation of the secondary coil and the primary coil and the vertical resolution of the secondary coil and the primary coil.

36. (Original) The method of claim 26, the calculating step further comprising calculating the high resolution measurement while drilling a borehole.

37. (Original) The method of claim 26, wherein the primary coil and the secondary coil are arranged in a non-overlapping configuration along the axis of the apparatus.

38. (Original) The method of claim 37, wherein the secondary antenna is located near a proximate end of the main antenna measured along the longitudinal axis of the NMR measurement apparatus.

39. (Original) The method of claim 37, wherein the secondary coil is located a distance from the primary coil that minimizes an electrical coupling between the secondary coil and the primary coil .

40. (Original) The method of claim 37, wherein the second coil is operated in an active mode as both a transmitter and a receiver.

41. (Original) The method of claim 40, wherein the secondary antenna selectably transmits a portion of an NMR acquisition sequence

42. (Original) The method of claim 40, wherein the primary coil is selectably operated in either a passive or active mode.

43. (Original) The method of claim 26, wherein at least a portion of the first surface area overlaps the second surface area.

44. (Original) The method of claim 26, wherein the secondary antenna is embedded in the primary antenna.

45. (Original) The method of claim 44, wherein the second coil is operated in a passive mode as a receiver of signals produced in response to a transmission by the first coil.

46. (Original) The method of claim 44, wherein the second coil is operated in an active mode as both a transmitter and a receiver.

47. (Original) The method of claim 46, wherein the secondary antenna selectably transmits a portion of an NMR acquisition sequence

48. (Original) The method of claim 46, wherein the primary coil is selectably operated in either a passive or active mode.

49. (Original) The method of claim 26, the secondary coil further comprising:
an array of secondary coils arranged in a non-overlapping configuration along the axis of the apparatus.

50. (Original) The method of claim 49, wherein the array of the secondary coils comprises a pair of secondary coils, each of the pair of secondary coils situated at opposite proximate ends of the primary coil measured along the longitudinal axis of the NMR apparatus.

51. (Original) The method of claim 49, the array of secondary coils further comprising:

a first plurality of secondary coils having a radiation polarization orthogonal to a radiation polarization of the primary coil; and

a second plurality of secondary coils having a radiation polarization parallel to the radiation polarization of the primary coil, wherein the secondary coils of the first plurality are alternated with the secondary coils of the second plurality.

52. (Original) An NMR measurement apparatus, comprising:
a permanent magnet;
an array of coils situated along a longitudinal axis of the apparatus;
a circuit coupled to the array of coils adapted to perform high resolution NMR measurements of an earth formation.

53. (Original) The NMR measurement apparatus of claim 52, wherein at least two coils of the array of coils have different pre-polarizations times.

54. (Original) The NMR measurement apparatus of claim 52, wherein a spin-lattice relaxation estimate based on a combination spin echo measurements from at least two of the array of coils.

55. (Original) The NMR measurement apparatus of claim 52, wherein at least one coil of the array of coils is operated in an active mode as both a transmitter and a receiver.

56. (Original) The NMR measurement apparatus of claim 55, wherein at least one of the active coils transmits a portion of an NMR acquisition sequence

57. (Original) The NMR measurement apparatus of claim 55, wherein at least one coil of the array is selectably operated in either a passive or active mode.

58. (Original) The NMR measurement apparatus of claim 52, the array of coils further comprising:
A first plurality of coils;

A second plurality of coils having a radiation polarization orthogonal to a radiation polarization of the first plurality of coils, wherein the coils of the first plurality are alternated with the coils of the second plurality.

59. (Original) The NMR measurement apparatus of claim 52, the array of coils comprising:
a primary coil extending across a first surface area, the primary coil having an associated depth of investigation and an associated vertical resolution and producing an RF field in a volume of earth formation;
a plurality of secondary coils, each secondary coil extending across a second surface area, the second surface area less than the first surface area, the secondary coil for receiving spin echoes from a volume of an earth formation at a depth of investigation associated with the secondary coil.

60. (Original) The NMR measurement apparatus of claim 59, wherein the plurality the secondary coils comprises a pair of secondary coils, each of the pair of secondary coils situated at opposite proximate ends of the magnet measured along the longitudinal axis of the NMR measurement apparatus.

61. (Original) The NMR measurement apparatus of claim 60, wherein the primary coil is situated between a pair of secondary coils.

62. (Original) The NMR measurement apparatus of claim 60, wherein the each coil of the pair of secondary coils has a different pre-polarization time.

Rejection of claims 1 and 26 under section 112, second paragraph

Applicant's respectfully assert that the claim terms "less than" are definite in that those terms provide a relative relationship between the size of surface area associated with the primary antenna and the size of the surface area associated with the secondary antenna. Specifically, the secondary antenna takes up less surface area than the primary antenna. Applicant points out in the specification the importance of a high resolution antenna having smaller dimensions than a primary antenna with larger dimensions having a lower resolution.

Rejection of independent claims 1, 26 and 52

Heaton does not teach or suggest a secondary coil having a vertical resolution that is higher than a vertical resolution of a primary coil. In Heaton, various multiple antenna configurations are disclosed along the axis of the tool. See, Heaton, figures 2-4. The various antenna spacings are employed to establish different polarization times for the MR measurements. (Abstract and col. 5: 36-42.) In fact the entire disclosure of Heaton is directed to improved methods to measure distributions of polarization times. In Heaton, long antennas are used to provide measurements of the full T2 distribution, while short antennas are uses to provide measurements of short polarization times. (Col. 9:58-62.) However, there is not mention for employing multiple antennas, at least one of which having a higher vertical resolution than the other antenna(s). High resolution measurements are not the subject of the Heaton patent.

Rejection of dependent claims 18, 43

Heaton does not teach or suggest a primary and secondary coil configuration where the primary coil and the secondary coil overlap. Specifically, with reference to figure 6 of